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ABSTRACT

Some of the essential elements now deficient in national energy programs are identified, and recommendations are offered for business, universities, and government regarding actions that may improve energy-related research and training. Five topics that need to be addressed by professionals are: (1) an energy policy that ensures that targets for both domestic energy supply and energy consumption are consistent, to reduce or eliminate dependence on imported oil; (2) an energy supply system involving a mix of technologies that are both sustainable and socially acceptable; (3) a sufficient knowledge base from which to evaluate the benefits and costs of different long-term energy technologies and strategies; (4) an understanding of long term energy demands; and (5) public attitudes toward technology, government, social institutions, and the quality of life that will strongly influence future energy policies and programs. It is suggested that expansion of goal-oriented basic research and other improvements will depend on a good cooperative working relationship among business, higher education, and government. Descriptions of cooperative efforts are appended. Among the recommended actions are: business and industry should increase support of university goal-oriented basic research and programs for training professionals; higher education should establish faculty-administration-board committees to seek ways to improve the flow of activity on research and training between each institution and relevant industry; higher education should establish an energy agenda setting priorities and the activities needed to respond to the energy problem; government needs to encourage private sector action; and Congress should enact legislation to provide tax incentives for business to increase its support of basic and goal-oriented research. (SW)

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THE NATION'S
ENERGY PROBLEM

Forum Report

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THE NATION'S ENERGY PROBLEM

The United States, it is generally agreed, faces a serious energy problem. Finding appropriate solutions will test the combined resolve and resourcefulness of industry, universities, government agencies, and citizens. Policies and programs need to be formulated that will ensure a smooth transition from dependence on fossil fuels to new energy sources which will afford more efficient uses while holding the social and economic costs of that transition to acceptable levels. The nation's future economic vitality, international competitive stature, and security depend on using our own resources in solving this formidable problem.

To meet this challenge, the nation must chart a path through a wide range of economic, political, scientific, and technological possibilities, and do so amid great uncertainty and disagreement about preferred courses of action. The process will be tempered by events, domestic and foreign, which are largely unpredictable, and shaped by estimates of future domestic supply and demand, which are highly dependent on the nation's desired social goals. Because the energy problem is complex on many levels, solving it requires an interdisciplinary approach and contributions from the best thinkers our country has available.

Research, development, and the training of professional people are all vital for making progress in energy matters. New investments in a range of research endeavors,¹ together with the indispensable training of scientists and engineers, are required. Today, the nation suffers from inadequate levels of investment in energy research and training, most notably in goal-oriented basic research. This statement identifies some of the essential elements now deficient in national energy programs and offers recommendations designed to improve the nation's position.

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INADEQUATE KNOWLEDGE BASE

Serious deficiencies of knowledge impede decision makers and the public in setting overall energy goals and developing the components of the nation's future energy system. Although in some areas experience will remain the best teacher, much of the required information must be provided by research. There are at least five topics that need to be addressed by professionals in government, business, and higher education.

1. Research in all the following categories is needed:

Discipline-oriented basic research: seeks the discovery and understanding of fundamental phenomena independent of specific energy goals (e.g., plasma physics, geochemistry, surface chemistry).

Goal-oriented basic research: uses the paradigm of basic science but seeks particular kinds of knowledge required in certain areas (e.g., research in photovoltaics, combustion, aerosol chemistry, coal-structure chemistry, systems modeling, risk analysis).

Applied research: makes use of existing basic knowledge in the study of particular energy technologies or systems (e.g., research on solar-thermal collectors, chemical engineering studies of coal conversion, reactor safety studies).

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First, in the short term, the most pressing need in the nation's energy policy is to ensure that targets for domestic energy supply and targets for energy consumption become consistent, so as to reduce or eliminate our costly dependence on imported oil. With respect to demand, research is required to improve understanding of the near-future potential for energy savings through cost-effective, technical means for increasing the end-use efficiency of energy in all sectors of the economy. More information is needed about the magnitude of financial investments required; about the best ways to bring about those investments, including the appropriate extent of government regulation and financial involvement; and about social and institutional impediments to increased energy efficiency, including distribution and equity problems arising from higher energy prices.

With respect to energy supply, the greatest need is to know the rate at which the domestic energy-supply system can be expanded, especially to fill needs for fluid fuels, for which a critical domestic supply-demand imbalance is likely to develop in the late 1980s. We need to understand the possibilities for, and constraints on, a rapid increase in production and use of domestic coal. We also need to understand the issues surrounding the expanded use of nuclear power. The potential role that can be played by solar and renewable technologies over the next two decades must become better understood.

Second, for the long term, the nation needs to develop an energy supply system containing an appropriate mix of technologies that are both sustainable and socially acceptable. Similarly, an energy demand structure should be formulated to be compatible with the expected future value of energy. At present we have few long-term supply options. A considerable amount of research and development is necessary to bring to readiness the nuclear breeder or other advanced reactor options, a wide range of solar-based technologies, use of geothermal energy, and fusion. The nation lacks sufficient information to decide now on an appropriate mix of these long-term systems. An important need is dedication to a broad and continuous program that will provide the knowledge base upon which to determine the most appropriate mixes of energy sources.

Third, today's knowledge is insufficient to evaluate the comparative benefits and costs of different long-term energy technologies and strategies. Reliable integrated assessments covering the entire spectrum of physical and social risks and impacts need to be made. The assessments should cover alternative long-term systems combining different mixes of energy sources, as well as different long-term strategies, including widespread deployment of decentralized and renewable systems. The availability of such assessments could greatly affect policy choices of energy supply alternatives and overall energy strategies. A major question to be addressed is, How can we more precisely determine the comparative costs, risks, and impacts of alternative long-range technologies and energy strategies that employ different mixes of new and conventional energy sources, including coal, nuclear, hydrogen, solar, wind, and synthetic liquid fuels?

Fourth, gaining an understanding of long-term energy demand—the practical and economic limits to the physical efficiency of energy and

to materials use — is an important and neglected element in the energy problem. Research should be supported that would lead to improving energy-use efficiency in fundamental ways; that would look at long-term world energy needs in relation to U. S. supply and demand and to the global situation. The United States, for example, must seriously examine what effects — hard to estimate but possibly overwhelmingly important — on climate and agriculture may result from continuing to use fossil energy technologies. Fundamental information is needed about the geographical distribution of society's activities, the recycling of materials, enhanced product repair and reuse, and the development of energy-efficient structures and products. Specific steps must be taken to address these problems.

Fifth and finally, public perceptions and attitudes toward technology, government, social institutions, and the quality of life will strongly influence future energy policies and programs. The public must be better informed and their views more accurately assessed and taken into account. Programs must be developed toward this end.

Among other points of emphasis, goal-oriented basic research is largely missing from the present arrangements for federal support to energy-related research. Indeed, such research is weak generally in government funding patterns. Considerably more support needs to be given to this type of research, which falls in the boundary area between basic science and mission application.

Central to the capability of universities to carry out energy-related research of all kinds and advanced training is the steady erosion of university research facilities. Many of the nation's leading university research and instructional laboratories are obsolete, impairing the quality of research and advanced training that can be carried out in them. The nation lacks a comprehensive approach toward renewing these essential facilities.

A significant improvement is needed in the working relationships between business and higher education on research activities. Professionally trained engineers, scientists, and other researchers — uniquely supplied by our universities — are the life blood of the nation's expanding, innovative industrial base. Yet there is a shortage of enrollments at the graduate level in such key fields as engineering and computer sciences. Steps must be taken to solve a host of problems concerning graduate-level education for critically needed scientists and engineers. On this score, business and higher education clearly share mutual dependence.

In view of this interdependence, it is unfortunate that the working relationships on research issues have gradually deteriorated. This weakening has damaged the traditional bonds, born especially of goal-oriented basic research, which have motivated both academic and business leaders toward closer cooperation. Both sectors, in cooperation with government agencies, must increase and improve communications so as to assure a better understanding both of problems and of mutually acceptable courses of action. Expansion of goal-oriented basic research and other improvements will depend on a healthy, cooperative working relationship among business, higher education, and government. In general, such cooperation is vital to the restoration of our nation's innovative leadership. Many of the present concerns for the health of the

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nation's research base stem from inadequate attention to forming and maintaining such relationships. Nevertheless, excellent examples of cooperation do exist and demonstrate the potential benefits of such activities. The programs and initiatives described in the appendix represent a start on strengthened understanding between business and higher education.

RECOMMENDATIONS

Many of the nation's leading university research and instructional laboratories are obsolete, impairing the quality of research and advanced training that can be carried out in them.

The efficient conduct of energy-related basic research and training is being inhibited by certain structural and policy barriers. These must be corrected as specific research programs are initiated or enhanced. The following recommendations provide a framework within which business, higher education, and government can collectively address the central scientific, technological, social, and policy questions of our national energy dilemma.

Industry Actions

- Especially those corporations that rely heavily on scientific and technical knowledge should fund a larger share of university-based goal-oriented basic research. Industry leaders are urged to invest in goal-oriented basic research at a set, reasonable percentage of annual net sales.
- Corporations should review and upgrade their support to university programs for training professionals, especially in disciplines of interest to the corporations. Fellowships and grants should be offered at dollar levels more in line with today's inflated costs.
- Industries and universities should continue to cooperate on new ways to generate joint goal-oriented research projects. Examples (some are summarized in the appendix) provide useful guidelines.
- Industry trade associations or whatever coordinating organization is appropriate should take a leadership role in working with their disciplinary counterparts in universities to explore ways in which the industrial sectors can encourage improved research and training activities.

University Actions

- Colleges and universities should establish faculty-administration-board committees to seek ways to improve the flow of activity on research and training between each institution and relevant industry, with particular attention to critical national problems such as energy.
- To facilitate the development and management of joint projects, universities should continue to improve their financial management systems, consistent with recommendations by the National Commission on Research and the resolution of the Association of American Universities (October, 1980) which endorsed certain of the commission's recommendations.²
- Universities should reevaluate their records, policies, and practices on

2. National Commission on Research, *Accountability: Restoring the Quality of the Partnership* (Washington, D.C.: NCR, March, 1980), 33 pp.

the distribution of effort among basic research, goal-oriented basic research, and applied research. They should consider, in particular, ways to increase activity in goal-oriented basic energy research.

- Universities need to clearly state their own priorities when seeking assistance from business and government. The American Council on Education—and the institutions of higher learning that make up its membership—should fashion an energy agenda setting priorities for research projects, laboratory rehabilitation, graduate and professional education, and other activities needed to respond to the nation's energy challenge.

Governmental Actions

- As a general rule, government needs to encourage private sector action by all possible means in meeting the nation's energy challenge. Because an important part of that challenge develops from the OPEC oil cartel, which distorts private initiative, government still has a major role to play. This outside influence suggests the imperative of closer understanding and cooperation between the public and private sectors. Although the federal role is important, it should not be misconstrued to minimize the private sector role in funding, which indeed, in many instances, is preferred by universities over government funding of research and training activity.

- Congress should enact legislation to provide tax incentives for business to increase its support of basic and goal-oriented basic research. Various plans have been recommended by national groups in the past, but action has been lacking. Now, with President Reagan's emphasis on national economic revitalization, the time is right to pursue tax incentives on Capitol Hill beyond those enacted in the 1981 tax-cutting bill. The United States is a world-class technological society; its industry depends on advanced research and development. American productivity is similarly dependent. Tax incentives to encourage research cooperation between higher education and business is generally a sound approach. It would be particularly helpful in encouraging energy research.

- The federal government should develop more programs, such as the Department of Energy's proposed energy-related traineeship program, to foster graduate education in key energy-related fields. The training of the next generation of researchers and leaders for the energy community is an essential component of ongoing energy research.

- Suggestions made by the Office of Science and Technology Policy Working Group concerning Department of Energy basic research (1978 Buchsbaum Report) should be adopted.³ Especially needed is an agencywide basic research coordinating committee, with advisory subgroups in appropriate goal-oriented and disciplinary areas, whose participants would include representatives from universities, industry, and federal laboratories. If strengthened, the Energy Research Advisory Board

3. Office of Science and Technology Policy, *Report of the Office of Science and Technology Policy Working Group on Basic Research in the Department of Energy* (Washington, D.C.: Executive Office of the President, June, 1978), 35 pp.

America's international preeminence in science and technology is the clearest evidence of the success of past investments in research, development, and professional training by government, universities, and industry.

(ERAB), reporting to the Secretary of Energy, could perform this role.⁴

- A sustained governmental and industrial investment strategy for the rehabilitation of university research laboratories is required, and legislation and tax incentives should be enacted accordingly. For its part, the federal government should begin by undertaking a program funded at a level at least equal to that proposed in FY 1982 for upgrading federal laboratories in order to modernize those university laboratories that carry out government-supported basic research and training.
- The executive branch of government, including the Office of Science and Technology Policy, and the Energy Research Advisory Board, the National Science Board, and the Defense Science Board, should undertake an integrated policy review and planning effort to develop appropriate governmentwide policies that will strengthen federal investments in energy-related basic research, particularly goal-oriented basic research and related advanced training. In addition, the director of the Office of Energy Research should play a stronger role in central planning and coordination across all DOE research programs to ensure proper balance among them and prompt pursuit of new research opportunities. The solution to a number of energy research problems will require integrated programs, such as the development of interdisciplinary energy research programs as an integral part of the DOE research mission.
- All operating divisions of the Department of Energy should allocate a greater proportion of their research and development resources to support goal-oriented basic research. In addition, funding for the DOE basic energy sciences program should be increased considerably.
- The government agencies dealing with energy, especially the Department of Energy, should develop procedures for dealing more reasonably with proprietary and patentable data. Policies must be broadened if proper industry and university support is to be obtained. Procedures need to be worked out to protect proprietary ideas and data. Public Law 96-517 (December 12, 1980) is a major step toward a more uniform federal patent policy addressing some of the above problems. It remains for each agency to implement this law properly and to protect proprietary information as well.

America's international preeminence in science and technology is the clearest evidence of the success of past investments in research, development, and professional training by government, universities, and industry. Leaders in each sector must now mobilize their innovative and financial resources in new ways to meet a grave challenge that the energy problem presents to the nation's international stature and security.

The United States has no other choice than to activate a national energy research effort consistent with the magnitude of that challenge. Recommendations are offered here to stimulate public debate and to convey a clear message to the nation that members of the Business-Higher Education Forum, representing many of the nation's leading corporations and universities, are prepared to work together with government to act directly on that challenge.

4. These suggestions were endorsed by the Ad Hoc Energy Advisory Committee of the Association of American Universities. Their substance appears, along with a useful discussion of goal-oriented basic energy research, in Jack M. Hollander, "University Contributions to the National Energy Program: New Knowledge, New Talent, New Integration," in *Agenda for Business and Higher Education*, ed. Thomas M. Stauffer, (Washington: Business-Higher Education Forum, 1980). pp. 136-76.

APPENDIX

Cooperative Efforts Between Business and Higher Education: Some Examples

The Cooperative Automobile Research Program

Although the program has been dropped, the model embodied in the Cooperative Automobile Research Program has merit that should be remembered. The principal purpose of the program was to increase the level of basic scientific research underpinning automotive technology. The premise was that better understanding in key research areas will lead to improved automobiles—more efficient, safer, less polluting, and less costly to buy and operate—beginning in the 1990s.

In 1979, the leaders of the American automobile industry met with President Carter at the White House and agreed on a set of guiding principles for a new, mutually supported research program related to automotive technology. They decided to begin further discussions aimed at defining a formal agreement consistent with these principles. The continuing discussions were carried forward by the Office of Science and Technology Policy, the Department of Transportation, and the five domestic automobile manufacturers—American Motors, Chrysler, Ford, General Motors, and Volkswagen of America—and the cost was to be shared.

The projects funded under the program were to be

selected, in part, for their relevance to future automotive technology, that is, goal-oriented basic research. The government and industry agreed to a one-to-one matching program. The automobile manufacturers agreed among themselves to divide their share of the effort according to their share of automobile production in the United States.

An administrative framework was to guide the participants (automobile manufacturers and federal agencies) in their activities under the program. The program was to be operated as a confederation of relatively autonomous participants, each of whom would select and manage the projects supported with its share of the total funding under the agreement, consistent with their agreed-upon administrative and technical frameworks. The relative autonomy of each participant was meant to assure that a range of different ideas would be funded. The participants chose to support the research areas in varying degrees and selected differing institutional modes for supporting and organizing the work. Plurality of support was a well-accepted concept in basic research management because of the subjective and judgmental criteria necessary in project selection. The lessons of this program still merit careful attention.

The Rockwell Minority Graduate Program

Some years ago, Rockwell International Corporation became concerned about its inability to find and recruit minority professionals, especially blacks at the master's and doctoral levels in physical science and engineering specialties. At that time, blacks represented about 11 percent of the population, while those holding Ph.D's were only about 0.5 percent of the total. Meeting this problem head on, the Rockwell Science Center, using corporate funds, initiated a three-year program with Howard University and North Carolina Agricultural and Technical State University to establish a research base at those schools in the field of solid-state electronics.

The primary goal was to establish a high-quality, self-sustaining research program for the universities which, in turn, would produce graduate scientists in a field of much interest to Rockwell. First, laboratories were constructed and equipped, followed by a transfer of proprietary gallium arsenide technology applicable to solar cells. Professional

scientists from Rockwell, along with others from Cornell University, assisted the universities in establishing a complete graduate program. Later the National Aeronautics and Space Administration and the Department of Energy were solicited with proposals for continuing work in the field. Thus, a base was established that made the two schools self-sufficient in a new, growing research area, while simultaneously increasing minority opportunities in solid-state electronic careers.

The relationship continues today in a normal contractor-subcontractor mode, the catalytic phase having been completed. Subsequently, in a similar program, the Rockwell Science Center assisted New Mexico State University in establishing a nondestructive evaluation research effort. These programs, conducted cooperatively by the industry-university-government trio, not only contribute to the scientific research need but also to the broader societal need.

Business-Higher Education Cooperation

Individual corporations and universities have entered into a variety of bilateral agreements to advance cooperative research. Such models could be applied to energy research. The experience of the institutions involved in these arrangements is being surveyed, in preparation for pending reports to the General Accounting Office, Ford Foundation, and NSF.

MIT-Exxon and Harvard-Monsanto represent two combinations, frequently cited, as exemplary of university-industry agreements. Both programs make plain that patent and other obstacles, which some institutions and corporations have thought were insurmountable, can be overcome in a reasonable fashion. These combinations do generate problems, but the real and potential benefits are becoming manifest.

Chemical Industries Fund Model

To support research in chemical engineering at universities, a consortium of chemical companies is planning a mechanism to expand sharply nongovernment support. The plan was developed after conferences in Midland, Michigan, and Lehigh, Pennsylvania, in 1979 and 1980, respectively. Each corporation and university will work out its own arrangements, but the overall effort will be coordinated by a working group established by the conferences. This move represents a major effort at expanding research of benefit to all parties, without federal support. It also suggests a model for energy research.

A task force is making final plans for a chemical industries fund, through which chemical corporations would funnel resources for particular research projects in which they are interested. Other cooperative activity is planned. Probably as important as the specific plans is the opportunity for industry-university contacts through annual conferences on chemical engineering, at which technical papers are presented and a variety of ideas are considered. The value of such contacts and the opportunities for mutual cooperation gained through them should not be underestimated.

Standard Oil of Indiana Initiatives

Not wholly related to research but directed toward improving graduate education is a new program initiated by the Standard Oil Company of Indiana. It consists of three parts. First, a new program will identify (by visiting teams) needs for geoscience and engineering equipment in public universities and provide increases in the ongoing program of unrestricted departmental grants. Equipment obsolescence and faculty shortages have reached a near-crisis stage in Amoco's judgment, as identified by the National Academy of Engineering, the American Association of Engineering Societies, the Department of Energy, and the National Science Foundation.

A second program is designed to support research by young or new (or both) engineering faculty. Engineering faculty grants of \$20,000 a year will go to persons with three-year commitments. Funds are intended for use by the recipient for early career research and professional development activities.

The third program involves a significant increase in the number and size of graduate fellowships, which provide a \$10,000 annual stipend for each student and full payment of university tuition fees. An additional \$1,000 is provided to the university to defray associated expenses. So far the program has provided for three-year fellowships for twenty-two engineering students and three geophysics students.

Ford Motor Company Directly Funds Energy Research

Between 1974 and 1978 the trustees of the Ford Motor Company Fund gave grants totaling more than a half-million dollars to the California Institute of Technology to support comprehensive research in energy problems. Using these funds as seed money, Caltech was able to obtain additional funding from the Exxon Corporation, Standard Oil of California, and other sources. Thus far the seed money has funded twenty-eight new faculty research projects, and many of these projects are now continuing with federal support from the Energy Research and Development Administration or other agencies.

The Joint Industry-University Research Program, a Department of Energy initiative, represents another important approach to government contract research. In this program, Ford Motor Company, together with the Universities of Notre Dame, Michigan, and Tennessee, are conducting energy research in several areas of mutual interest to the Department of Energy, the Ford Motor Company, and the participating universities. A key objective of this program is the enhancement of the quality and relevance of the research through strong interaction between Ford and university personnel.